MATERIALS BUREAU

TECHNICAL REPORT 88-11

ALTERNATE CURING STUDY FOR REINFORCED CONCRETE PIPE-PHASE II

FINAL REPORT

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NEW YORK STATE DEPARTMENT OF TRANSPORTATION
MARIO M. CUOMO, Governor FRANKLIN E. WHITE, Commissioner

TECHNICAL REPORT 88-11

ALTERNATE CURING STUDY FOR REINFORCED CONCRETE PIPE - PHASE II

Prepared by

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November, 1988

MATERIALS BUREAU
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M.A.P. CODE 7.42-6-88-11

ABSTRACT

This joint study was initiated by the NYSDOT's Materials Bureau at the request of the NYS Concrete Pipe Association. Its purpose was to determine if air curing of reinforced concrete pipe (RCP) is sufficient to produce an acceptable product.

Phase I and Phase II (the final phase) of this study were done in the Fall of 1987 and Summer of 1988 respectively. During these times, air cured and steam cured machine made and wet cast RCP were manufactured, tested and compared for strength, absorption and freeze-thaw resistance. Tests showed little or no difference between the cure methods. However, freeze-thaw tests indicated that there is a durability problem with non air entrained wet cast RCP. Further action is needed on wet cast pipe.

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BACKGROUND

This joint study was initiated by the New York State Department of Transportation's Materials Bureau at the request of the New York State Concrete Pipe Association. Its purpose was to determine if air curing (as opposed to steam curing) of reinforced concrete pipe (RCP) is sufficient to produce an acceptable product.

Phase I of this study was initiated in the Fall of 1987. At that time 12, 24 and 36 inch diameter RCP were machine made by participating pipe producers using packerhead equipment. Half of these pipe were air cured while the others were steam cured in accordance with NYSDOT specifications. The pipes were then subjected to absorption, freeze-thaw and 3-edge bearing strength tests. Phase I was concluded when the test results were reported in Technical Report 88-1 "Alternate Curing Study For Reinforced Concrete Pipe, First Interim Report". The reported results showed no significant difference between air and steam cured machine made pipe, within the parameters of the environmental conditions experienced during the study period. Copies of this report are available from the NYSDOT Materials Bureau upon request.

The purpose of Phase II of this study, which is being reported here, was to determine if acceptable machine made and wet cast RCP could be produced and air cured during the Summer months when environmental conditions were more severe than those experienced in Phase I.

INVESTIGATION

Participant Responsibility

As previously stated, this was a joint study between the NYSDOT Materials Bureau and the NYS Concrete Pipe Association. As such, each assumed the following responsibilities;

	Materials Bureau		RCP Producers
(1)	Design the experiment	(1)	Manufacture and cure sample pipe at their facilities at no cost to the Department
(2)	Observe the manufacture of sample pipe and record mix design data	(2)	Provide mix design and curing data
(3)	Select sample pipe for strength and laboratory tests after curing	(3)	Core selected sample pipe for laboratory tests
(4)	Observe strength tests and record results	(4)	Conduct strength tests
(5)	Conduct laboratory tests for absorption and freeze-thaw	(5)	Collect weather data for 7 days after production
(6)	Report the results of the experiment		

Experiment Design

The experiment, designed for the second and final phase of this study, is entitled NYSDOT/NYSCPA ALTERNATE CURING STUDY, PHASE II and is presented in the Appendix.

Machine Made Pipe - In Phase I of this study, 12, 24 and 36 inch diameter Class III RCP were machine made and tested for absorption, freeze-thaw and strength after curing. Absorption and freeze-thaw test results were comparable for all three sizes. However, strength results for the 12 and 36 inch pipe were considerably higher than those achieved with 24 inch pipe when comparing the results against the minimum requirements specified for those sizes and class. Examination of the data revealed that this difference was due to the amount of wire mesh reinforcement used in the manufacture of each pipe size. Based on this, it was decided to machine make and test only 24 inch pipe in the Phase II portion of this study.

Wet Cast Pipe - Because the demand is minimal, some producers are not equipped to machine make larger RCP. Consequently, when these pipes are needed, they are often wet cast. To determine if acceptable air cured pipe could be produced by this method, 48 inch diameter wet cast pipe were included in Phase II of the study.

Sample Pipe Production, Curing And Testing

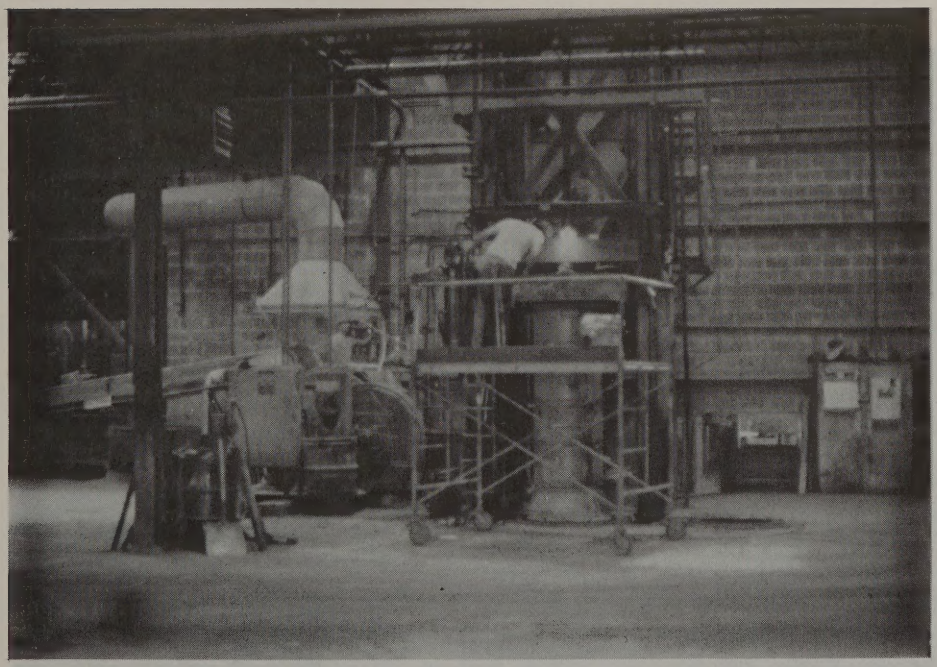
During the months of July and August of 1988, three RCP producers, manufactured pipe for the study. The 24 inch diameter pipe were made with packerhead equipment while the 48 inch diameter were wet cast in steel forms. The producers, along with the sizes and numbers of pipe they made were as follows;

Producer	Class III Pipe Dia. (Inches)	Number of Units
Boccard Industries Inc. Bayshore, NY	48	8
Bundy Concrete Products Inc. Watertown, NY	24	20
	48	8
L. S. Lee & Son Oaks Corners, NY	24	20
	48	8

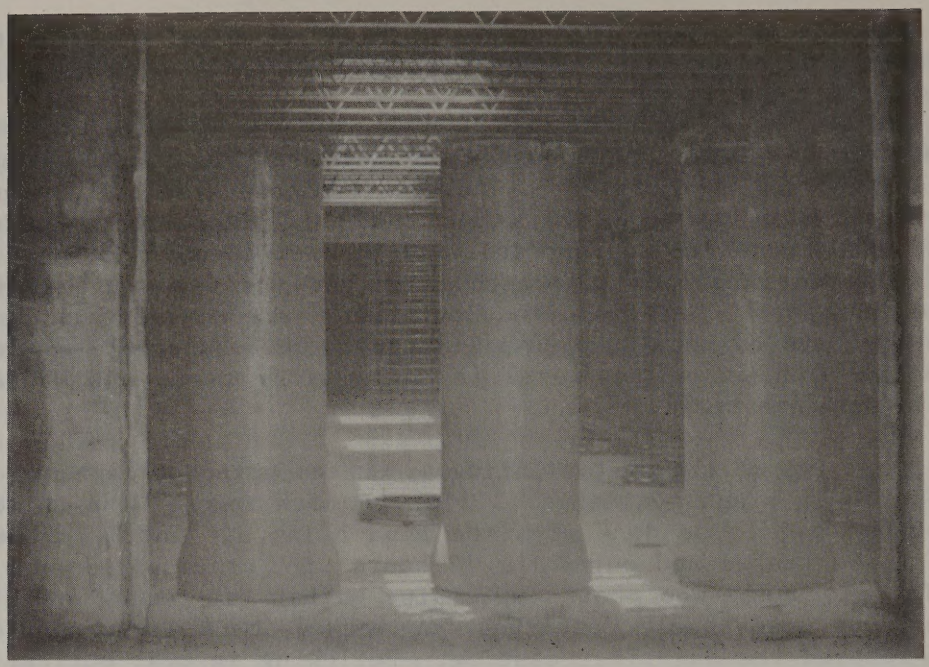
Personnel from the Materials Bureau and/or Regional Materials were present to observe sample pipe production, record pertinent data and select which pipe would be steam and air cured.

Machine Made Pipe - After these pipes were made within the confines of the plants, half were set in a curing bay to be steam cured while the other half were set in another curing bay to be air cured. Once in place, the outside forms were removed and the pipes were appropriately marked for identification. During the initial 12 hour cure period, temperatures within the bays were monitored by temperature recorders. The following day, rings were removed and the pipes were moved from the bays to outside stockpile areas. Here Materials Bureau personnel randomly selected pipes to be cored for laboratory tests and those to be subjected to strength tests.

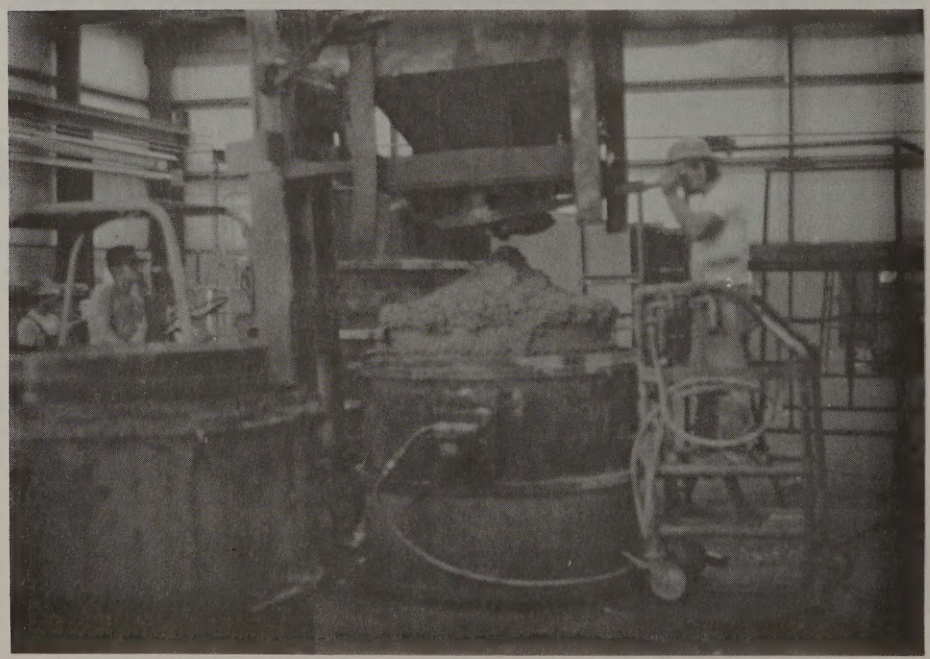
Wet Cast Pipe - Two of the participating producers opted to cast and cure sample pipe outside their plant buildings. Prior to form removal the following day, nothing further had to be done with the pipe being air cured. However, the others had to be tented and cured for 12 hours with steam piped from within the plants. The producer, who cast sample pipe within his plant, used the same curing procedure, previously described for machine made pipe, once the steel forms were removed the day after casting. Following initial curing, pipes were moved to stockpile locations where Materials Bureau personnel selected those to be cored for laboratory tests and those to be subjected to strength tests.



Twenty four inch diameter RCP being machine made
with Packerhead equipment

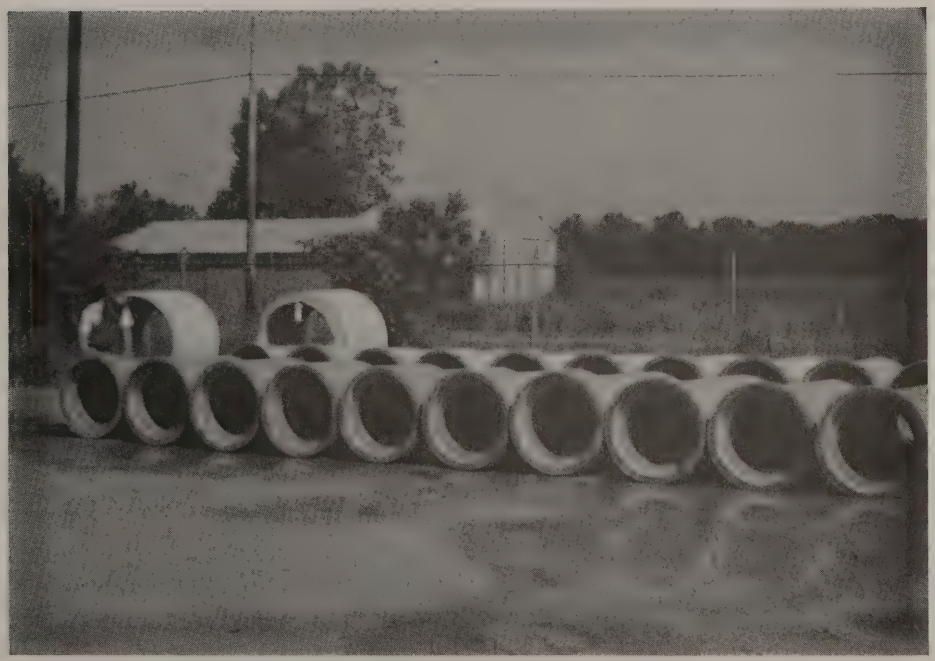


Twenty four inch diameter RCP were placed in curing bays, and their forms removed in preparation for either steam or air curing



Forty eight inch diameter RCP being wet cast inside a producer's plant

Forty eight inch diameter RCP being wet cast outside a producer's plant



RCP being marked for testing after it had been cured for 12 hours and moved to a stockpile area

For a period of about two weeks following pipe sample production, RCP producers took cores for absorption, freeze thaw and high pressure air tests, conducted the required strength tests and recorded weather data. All these activities were monitored by Regional Materials personnel.

In the Materials Bureau laboratory in Albany, absorption tests of cores were conducted seven days after sample pipes were made. Freeze-thaw testing began on the seventh as well as the fourteenth day after production. High pressure air tests were also performed on cores from air and steam cured wet cast pipe. Although air tests were not included in the experiment, as designed, it was of interest to know how much air had been entrained and entrapped within wet cast RCP samples.

The data obtained during sample pipe production and curing, along with the results of subsequent laboratory and strength tests, are presented in the summary forms that follow.

TEST RESULTS - MACHINE MADE RCP
N.Y.S.D.O.T. Materials Bureau

Company: Bundy Concrete Products, Inc.

Location: 548 Snell St., Watertown, N.Y. 13601

Production Date: 8/3/88
Pipe Diameter : 24 in.
Cement Factor : 767 lb./cy.
Rings Stripped : 20 hrs.
Steel Area : 0.08 sq.in.

STRENGTH - 7 DAY (lbs.)

*Sample	Load 0.01"	Ultimate
A-5	36,000	42,600
A-7	33,000	48,000
A-9	37,800	40,800
S-5	36,000	50,400
S-7	35,400	41,400
S-9	34,800	47,400

CURING CONDITIONS (7 Days)

Steam Temp.(F), Range: 90 - 124
Humidity (%), Range: 70 - 84
Low Temp. (F), Range: 62 - 83, avg 70
High Temp. (F), Range: 79 - 98, avg 90
Percent Rain: 4

ABSORPTION - 7 DAY CORES

*Sample	% Absorbed	*Sample	% Absorbed
A-4	5.9	S-4	5.7
A-6	6.0	S-6	6.1
A-8	6.2	S-8	6.4
Avg	6.03	Avg	6.07

FREEZE-THAW WEIGHT LOSS (%)

*Sample	7 Day Cores	14 Day Cores
A-10	0.0	0.4
S-10	0.0	0.0

REMARKS:

1) * A - Air cure; S - Steam cure

2) Strength requirements - Class III:

0.01" crack load: 2700 lb./ft. x 7.5 ft. = 20,250 lbs.
Ultimate load: 4000 lb./ft. x 7.5 ft. = 30,000 lbs.

3) Strength and Absorption determined by ASTM C497.

4) Freeze-Thaw Weight Loss determined by NYSDOT 502-3P using 3% NaCl, 25 cycles, one cycle per day.

TEST RESULTS - MACHINE MADE RCP
N.Y.S.D.O.T. Materials Bureau

Company: L.S. Lee and Son

Location: Oaks Corners, N.Y. 14518

Production Date: 7/27/88
Pipe Diameter : 24 in.
Cement Factor : 700 lb./cy.
Rings Stripped : 20 hrs.
Steel Area : 0.10 sq.in.

STRENGTH - 7 DAY (lbs.)

*Sample	Load 0.01"	Ultimate
A-2	21,500	31,250
A-4	22,500	34,750
A-6	22,000	35,750
S-2	28,250	34,500
S-4	27,500	36,500
S-6	31,750	42,750

CURING CONDITIONS (7 Days)

Steam Temp.(F), Range: 80 - 130
Humidity (%), Range: 47 - 92
Low Temp. (F), Range: 59 - 75, avg 68
High Temp.(F), Range: 88 - 103, avg 96
Percent Rain: 0

ABSORPTION - 7 DAY CORES

*Sample	% Absorbed	*Sample	% Absorbed
A-1	6.4	S-1	6.5
A-3	6.2	S-3	5.6
A-5	6.3	S-5	6.2
Avg	6.3	Avg	6.1

FREEZE-THAW WEIGHT LOSS (%)

*Sample	7 Day Cores	14 Day Cores
A-7	0.0	-
S-7	0.0	-

REMARKS:

1) * A - Air cure; S - Steam cure

2) Strength requirements - Class III:

0.01" crack load: 2700 lb./ft. x 7.5 ft. = 20,250 lbs.
Ultimate load: 4000 lb./ft. x 7.5 ft. = 30,000 lbs.

3) Strength and Absorption determined by ASTM C497.

4) Freeze-Thaw Weight Loss determined by NYSDOT 502-3P using 3% NaCl, 25 cycles, one cycle per day.

TEST RESULTS - WET CAST RCP
N.Y.S.D.O.T. Materials Bureau

Company: Boccard Industries, Inc.

Location: 45 South 4th St., Bayshore, N.Y. 11706

Production Date: 7/26/88 - 7/29/88
Pipe Diameter : 48 in.
Cement Factor : 752 lb./cy.
Forms Stripped : 18 - 20 hrs.
Steel Area : 0.24 sq.in. (inner cage)
0.18 sq.in. (outer cage)

STRENGTH - 7 DAY (lbs.)

*Sample	Load 0.01"	Ultimate
A-2	33,200	48,700
A-3	27,200	48,700
S-2	24,200	47,200
S-3	23,700	40,700

CURING CONDITIONS (11 Days)

Steam Temp.(F), Range: 90 - 125
Humidity (%), Range: 63 - 90
Low Temp. (F), Range: 70 - 76, avg 74
High Temp. (F), Range: 85 - 102, avg 93
Percent Rain: 5

ABSORPTION - 7 DAY CORES

*Sample	% Absorbed	*Sample	% Absorbed
A-1	7.0	S-1	7.0

FREEZE-THAW WEIGHT LOSS (%)

*Sample	7 Day Cores	14 Day Cores
A-1	5.4	67.5
S-1	18.5	69.1

HIGH PRESSURE AIR (%)

*Sample	14 Day Cores
A-1	2.5
S-1	2.6

REMARKS:

1) * A - Air cure; S - Steam cure

2) Strength requirements - Class III:

0.01" crack load: 5400 lb./ft. x 4.0 ft. = 21,600 lbs.
Ultimate load: 8000 lb./ft. x 4.0 ft. = 32,000 lbs.

3) Strength and Absorption determined by ASTM C497.

4) Freeze-Thaw Weight Loss determined by NYSDOT 502-3P using 3% NaCl, 25 cycles, one cycle per day.

5) Steam curing is outdoors under a tarpaulin.

6) High Pressure Air determined by NYS Test Method 307-78.

TEST RESULTS - WET CAST RCP
N.Y.S.D.O.T. Materials Bureau

Company: Bundy Concrete Products, Inc.

Location: 548 Snell St., Watertown, N.Y. 13601

Production Date: 8/3/88 - 8/4/88
Pipe Diameter : 48 in.
Cement Factor : 733 lb./cy.
Forms Stripped : 18 - 24 hrs.
Steel Area : 0.24 sq.in. (inner cage)
0.18 sq.in. (outer cage)

STRENGTH - 7 DAY (lbs.)

*Sample	Load 0.01"	Ultimate
A-3	25,000	33,500
A-4	29,000	41,000
S-3	24,500	34,500
S-4	24,500	33,500

CURING CONDITIONS (14 Days)

Steam Temp.(F), Range: N.A.
Humidity (%), Range: 70 - 84
Low Temp. (F), Range: 66 - 83, avg 73
High Temp. (F), Range: 84 - 98, avg 91
Percent Rain: 4

ABSORPTION - 7 DAY CORES

*Sample	% Absorbed	*Sample	% Absorbed
A-2	7.1	S-2	7.6

FREEZE-THAW WEIGHT LOSS (%)

*Sample	7 Day Cores	14 Day Cores
A-2	100 (@ 24)	100 (@ 21)
S-2	100 (@ 24)	100 (@ 21)

HIGH PRESSURE AIR (%)

*Sample	14 Day Cores
A-2	1.8
S-2	2.2

REMARKS:

1) * A - Air cure; S - Steam cure

2) Strength requirements - Class III:

0.01" crack load: 5400 lb./ft. x 4.0 ft. = 21,600 lbs.
Ultimate load: 8000 lb./ft. x 4.0 ft. = 32,000 lbs.

3) Strength and Absorption determined by ASTM C497.

4) Freeze-Thaw Weight Loss determined by NYSDOT 502-3P using 3% NaCl, 25 cycles, one cycle per day.

5) Steam curing is outdoors under a tarpaulin.

6) High Pressure Air determined by NYS Test Method 307-78.

7) Number of cycles included in chart when freeze-thaw weight loss = 100%.

TEST RESULTS - WET CAST RCP
N.Y.S.D.O.T. Materials Bureau

Company: L.S. Lee and Son

Location: Oaks Corners, N.Y. 14518

Production Date: 7/26/88 - 8/2/88
Pipe Diameter : 48 in.
Cement Factor : 700 lb./cy.
Forms Stripped : 18 - 24 hrs.
Steel Area : 0.30 sq.in. (inner cage)
0.18 sq.in. (outer cage)

STRENGTH - 7 DAY (lbs.)

*Sample	Load 0.01"	Ultimate
A-2	29,500	38,000
A-4	35,000	42,500
S-2	26,250	35,250
S-4	27,500	37,250

CURING CONDITIONS (21 Days)

Steam Temp.(F), Range: 80 - 130
Humidity (%), Range: 47 - 96
Low Temp. (F), Range: 48 - 77, avg 68
High Temp.(F), Range: 78 - 103, avg 92
Percent Rain: 12

ABSORPTION - 7 DAY CORES

*Sample	% Absorbed	*Sample	% Absorbed
A-1	6.5	S-1	7.2

FREEZE-THAW WEIGHT LOSS (%)

*Sample	7 Day Cores	14 Day Cores
A-1	12.9	23.0
S-1	100 (@ 25)	100 (@ 17)

HIGH PRESSURE AIR (%)

*Sample	14 Day Cores
A-1	2.2
S-1	2.0

REMARKS:

1) * A - Air cure; S - Steam cure

2) Strength requirements - Class III:

0.01" crack load: 5400 lb./ft. x 4.0 ft. = 21,600 lbs.
Ultimate load: 8000 lb./ft. x 4.0 ft. = 32,000 lbs.

3) Strength and Absorption determined by ASTM C497.

4) Freeze-Thaw Weight Loss determined by NYSDOT 502-3P using 3% NaCl, 25 cycles, one cycle per day.

5) High Pressure Air determined by NYS Test Method 307-78.

6) Number of cycles included in chart when freeze-thaw weight loss = 100%.

TEST RESULTS

Strength Tests

As evidenced by the preceding test results, all the machine made and wet cast pipe samples tested surpassed the specified minimum load requirements of the NYSDOT specifications. What is more significant is that strengths were not influenced by the curing method.

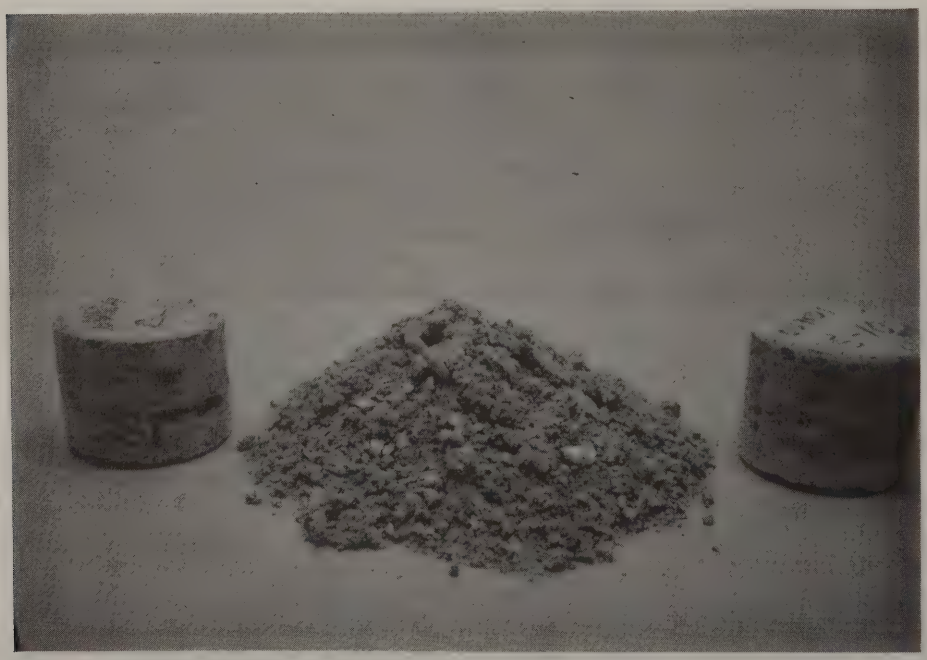
Absorption Tests

All core samples also passed the absorption test, the values obtained being less than the 8% by weight limit required by the NYSDOT specifications. Differences in absorption between air and steam cured samples were insignificant. However, results do indicate higher absorption for wet cast cores than for their machine made counterparts.

Freeze-Thaw Tests

Test results show no difference in freeze-thaw resistance between air and steam cured core samples. Consequently, the results were not influenced by the curing method.

There was, however, a considerable difference between core samples taken from machine made pipe compared to those taken from wet cast pipe. It was expected that better test results would be obtained with machine made pipe because their concrete mixes have lower water-cement ratios. In addition, the packerhead equipment provides better compaction than the internal or external form vibrators used for wet casting. As a result, machine made pipe is inherently denser and stronger than its wet cast counterpart. What was not expected, however, was that the difference would be so diverse, the machine made pipe exhibiting excellent freeze-thaw resistance compared to poor resistance in wet cast samples. Many wet cast core samples showed 100% loss while others showed percent losses ranging from 5 to 70%. Judging from their physical appearance after testing, however, it was apparent that they would also have failed completely had cycling continued longer.



Air and steam cured cores from machine mad pipes (left and right) compared to a core fro a wet cast pipe (center) after the three had been subjected to freeze-thaw tests

CONCLUSIONS

Based on the tests performed and observations made during both phases of this study, the following conclusions are warranted for RCP produced during the Spring, Summer and Fall months when ambient temperature is 50°F and above during the first 12 hours of curing.

1. RCP producers have demonstrated that air cured as well as steam cured machine made or wet cast pipe can be made to meet NYS specifications for absorption and strength.

2. Wet cast RCP is slightly more absorptive than its machine made counterpart.

3. When subjected to laboratory tests, both air and steam cured machine made RCP without air entrainment demonstrate excellent freeze-thaw resistance.

4. When subjected to laboratory tests, both air and steam cured wet cast RCP without air entrainment demonstrate poor freeze-thaw resistance.

RECOMMENDATIONS

With the completion of Phase II, this joint study is concluded. Based on the preceding conclusions, recommendations are as follows:

1. The Materials Bureau should take the action necessary to allow air curing of machine made RCP only.

2. The Materials Bureau should also take action to improve the durability of wet cast RCP.

APPENDIX

NYSDOT/NYSCPA Alternate Curing Study
For Reinforced Concrete Pipe - Phase II

NYSDOT/NYSCPA
ALTERNATE CURING STUDY
PHASE 2

GENERAL

A modified curing method will be compared to the standard 12 hour steam cure. Each participating manufacturer will produce pipe with Lots of varying diameter pipe, machine made and cast.

Pipe shall be manufactured in standard 8', 7'-6" or 4' (for larger diameter) lengths. The pipe sections will be marked so as to preserve the identity of each piece. The modified curing method will be permitted only when temperatures remain at 50°F or above.

A. CURING METHODS

See attachment. A modified and a standard procedure will be used.

B. PIPE SIZE & CLASS

See attachment. Pipe sizes of 24" and 48" diameter shall be used for this study. Pipe shall be Class III and shall be the same for all manufacturers.

The 24" size shall be machine made and the 48" size shall be cast.

C. QUANTITIES

For each diameter pipe and method of curing, each participating manufacturer will manufacture a Lot of ten (10) sections of machine made pipe and four (4) sections of wet cast pipe. See attachment.

D. EQUIPMENT

A temperature recorder shall be provided by the manufacturer to measure temperature in the enclosure for the initial 12 hour cure period. Daily humidity, high-low temperature and weather conditions for the next 7 days (14 days in the event of a failing test) will be recorded by the manufacturer on the form attached. The manufacturer will furnish the high-low thermometer for the collection of temperature data. Humidity may be taken from local weather reports.

E. TESTING

See attachment. All testing will be performed immediately at the end of seven (7) days of curing or as approved by the Director, Materials Bureau.

F. DOCUMENTATION

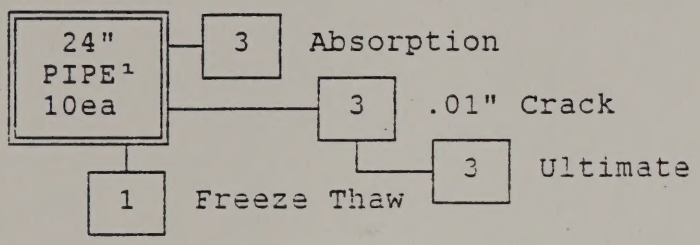
All manufacture, curing and testing will be conducted in the presence of a representative of the Department.

G. ACCEPTANCE

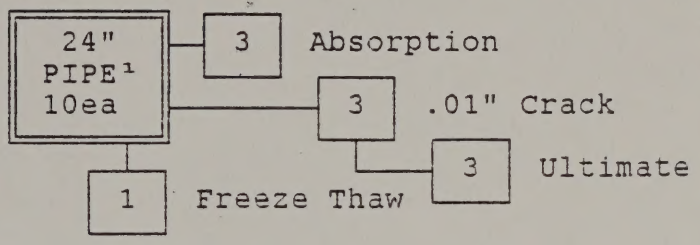
Only pipe manufactured in accordance with the standard curing method will be considered for acceptance.

NYSDOT/NYSCPA
ALTERNATE CURING STUDY
PHASE 2

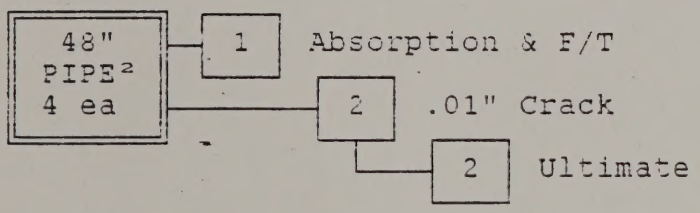
STANDARD CURING METHOD

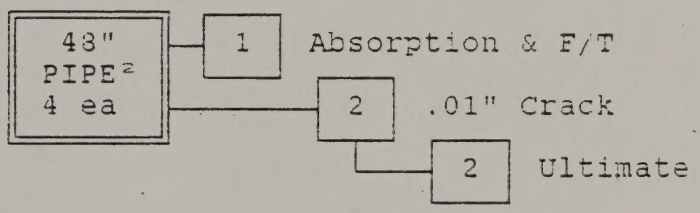


MODIFIED CURING METHOD



(1) Three pipes held in reserve in the event failure occurs at 7 days.





(2) One pipe held in reserve in the event failure occurs at 7 days.

NOTES:

STANDARD CURING METHOD:

Steam for 12 hours as per 706-02, Section 3.C-1

MODIFIED CURING METHOD:

Machine Made - Pipe set in kiln, forms removed but no steam applied.

Wet Cast - Cover over top of form (or curing compound with fugitive dye) applied immediately. Cover, forms and rings to be removed after curing for 12 hours (min.).

4/22/88

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LRI